AMENDMENTS TO THE SPECIFICATION

On Page 1, immediately preceding "FIELD OF THE INVENTION" please insert the following:

--This application is a continuation of U.S. Patent Application Serial No. 10/193,943 filed July 12, 2002, which is a continuation of U.S. Patent Application Serial No. 09/249,680 filed February 12, 1999, the entire disclosure of both such applications being incorporated by reference in their entirety herein.—

Paragraph [0003] on pages 1-2 of the original patent application has been amended in the following manner:

[0003] In order to make appropriate welds, the pin tool or ligament 22 of FIGURE 1 must be maintained at a depth which provides full hot working of the desired region of the workpiece 14. The depth of plunge of the pin tool 22 is the depth to which the tip 28 of the pin tool 22 extends below the upper surface 14us, which is the surface from which the pin tool 22 is introduced into the workpiece 14. The depth of the plunge cannot be such that the tip 28 of pin tool 22 extends beyond the second or lower surface ~~14~~ 14ls of the workpiece 14, because this might weld the workpiece 14 to the anvil 12, or might damage the workpiece 14 or pin tool 22. In U.S. Patent ~~a~~Application Serial No.~~09/006,915~~09/036,915, the position of the pin tool is maintained at the appropriate level by a set 26 of rollers, only one of which, namely roller 26a, is illustrated in FIGURE 1. Roller 26a is affixed by a shaft 26s to the spindle or tool holder 18, and rotates therewith, bearing on the upper surface 14us of the workpiece 14. The position of the tip 28 of the pin tool 22 in this prior-art arrangement extends below (or beyond) the lower rolling surface of the rollers 26 by the desired penetration of the workpiece 14. The penetration of the workpiece 14 may be termed "axial" penetration, because the

penetration is in a direction coincident with, or at least parallel to, the axis of rotation 8 of the spindle 18 and the pin tool 22.

Paragraph [0007] on page 3 of the original patent application has been amended as follows:

[0007] A method according to the invention for stir-friction welding a planar workpiece uses a rotating pin tool which includes a pin or ligament. The pin or ligament defines a diameter at locations closer to the tip of the pin tool that is less than a diameter at a particular location along its length, and also includes or defines a shoulder at the location. The shoulder has a larger diameter than the pin. The method includes the steps of rotating the tool, and applying force to the pin tool with the pin tool plunged into one side of the workpiece, and with the shoulder essentially coincident with the surface of the one side of the workpiece, so that the rotating pin creates a friction-stirred region. According to an aspect of a method according to the invention, the workpiece and the rotating tool are moved laterally (in a direction orthogonal to the axis of rotation) relative to each other, so that the friction-stirred region progresses along the workpiece. During the moving step, a signal is generated which is representative of the force applied to the pin tool. A reference signal is generated which is representative of that force which is sufficient to maintain the shoulder against the one surface of the workpiece. The signal representative of the force applied to the pin tool is compared with the reference signal, for generating an error signal representative of the difference between the force applied to the pin tool and the reference signal. The error signal is used to control the step of applying force in a manner tending to maintain the shoulder in contact with, or essentially coplanar with, the one surface of the workpiece, as a result of which, or whereby, the pin maintains substantially constant plunge depth.

Paragraph [0012] on pages 5-6 of the original patent application has been amended as follows:

[0012] FIGURE 3 illustrates the pin tool 222 of FIGURE 2 separate from the spindle 18. As illustrated in FIGURE 3, the pin tool 222 includes a shank 310 in addition to the shoulder portion 224 and pin or ligament 22. ~~The grooves cut into the pin support in FIGURE 3 are for ________________.~~

Paragraph [0013] on page 6 of the original patent application has been amended as follows:

[0013] FIGURE 4 is a simplified diagram illustrating one method for applying force to the pin tool in accordance with an aspect of the invention. In FIGURE 4, a fixed frame or housing 410 defines an aperture 412 for accommodating and supporting a first bearing 414, and also defines a second mounting region 416, to which a load cell 418 is mounted. Load cell 418 is a device which transduces force or pressure into electrical signals, which are available on a signal conductor set 420. Load cell 418 supports a bearing holder 422, which holds a bearing 424. A threaded shaft or lead screw 430 extends between bearings 414 and 424, and is rotatable about its axis 408. A first motor 450 is connected to a gear or worm 451 which engages lead screw 430, for, when the first motor 450 is energized, driving lead screw 430 to rotate around its axis 408. A mounting or head 440 is mounted in a movable fashion, and is mechanically coupled to the threads of lead screw 430 by a pair of threaded bosses or traveling nuts 440_1 and 440_2. Head 440 is controllably driven in the directions of arrow ~~46~~27 by rotation of lead screw 430. Thus, rotation of motor 450 in a first direction results in linear motion of head 440 in a first direction, and rotation of motor 450 in a second direction results in linear motion of head 440 in a second direction. Motor 450 is energized with electrical power transmitted over conductor set 452. A computer or processor (PROC) 460 produces appropriate control signals, which are amplified by a power amplifier illustrated as 454

before application by way of conductors 452 to motor 450. Processor 460 receives load-cell signals over conductor set 420, and processes the signals as described in more detail below, to control the position of head 440 and its pin tool 222.

Paragraph [0015] on pages 6-7 of the original patent application has been amended as follows:

[0015] Head 440 of FIGURE 4 supports shaft or spindle 18 on a pair of bearings 441a and 441b. Spindle 18 is affixed to a circumferential gear 442. A spur gear 444 driven by a second or spindle motor 446 engages circumferential gear 442, and drives the spindle 18 with a rotary motion in response to energization of motor 446. During operation of the apparatus of FIGURE 4, spindle motor 446 is driven with a constant velocity, while lead-screw motor 450 is driven in response to signals from load cell 418.

Paragraph [0017] on pages 7-8 of the original patent application has been amended as follows:

[0017] FIGURE 5a illustrates details of the shoulder 224, and FIGURE 5b illustrates as a plot 500 the relative force tending to resist the plunging of the rotating tool 222 into a workpiece, plotted against the position or depth of the pin tool 22~~,~~. As can be seen in FIGURE 5a, shoulder 224 is not absolutely flat, but is slightly cone-shaped or tapered, in such a manner that the outer edges of the shoulder 524r, as measured from the axis ~~28~~29 of rotation, are slightly behind (more distant from) the inner or leading portion ~~524~~ 524, as measured from the tip 28. The plot 500 of FIGURE 5b can be interpreted by noting that at the moment at which the tip 28 of pin tool 22 comes into contact with the workpiece, corresponding to position 510 of FIGURES 5a and 6b, the force is at or near zero. As the pin tool is plunged through the material of the workpiece so that the tapered tip portion 28t of the pin tool enters the material of the workpiece, the force represented by plot 500 increases, and

eventually reaches a level A. The level A is reached as the plunge depth is such as to bring the upper surface of the workpiece to the position indicated as 512. Further plunging of the tool 222 into the workpiece, represented by those positions between position 512 and 514 of FIGURE 5b, cause a slight increase in the force necessary to produce further penetration, because a portion of the cylindrical portion of the pin tool lies within the workpiece, and its sides are in contact with the workpiece, and tend to resist axial motion. At some level of penetration, illustrated as level ~~516~~514, the upper surface 14u of the workpiece begins to contact the leading edge ~~524~~ 524 of shoulder 224, and the force required for further penetration increases sharply. The corner is designated 501, and the corresponding force is designated B. The maximum force C illustrated in plot 500 represents a condition in which the upper surface 14u of the workpiece 14 is even with outer portion 524r of the shoulder 224 at its maximum radius from the axis ~~28~~29.

Paragraph [0019] on pages 8-9 of the original patent application has been amended as follows:

[0019] Considering the characteristics of plot 500 of FIGURE 5b, it will be understood that the plotted forces tending to resist further penetration of the rotating pin tool increase in a monotonic manner with increasing penetration, although with different slopes for different penetrations. FIGURE 6 is a simplified diagram of a feedback control arrangement, which may be implemented by processor 460 of FIGURE 4, for control of lead-screw motor 450 in such a manner as to tend to maintain constant pressure or force on the pin tool 222. In FIGURE 6, processor 460 includes a source of signal 610 which represents the desired pressure or force which is to be applied to the pin tool. The signal representing the desired pressure or force is applied to the noninverting (+) input port of a summing circuit 612. Summing circuit 612 also receives at an inverting (-) input port a signal representing the actual force applied to the load cell 418. The force applied to the load cell

418 is the reaction force arising from the force applied by the lead screw 430 to the head 440 to drive the head 440, and the pin tool with it, toward the workpiece 14. Summing circuit 612 acts has an error signal generator, and subtracts the actual-pressure or actual-force signal from the desired-pressure or desired-force signal, to thereby produce an error signal. The error signal is applied to control the lead-screw motor 450 in a bidirectional manner. The motor 450 is connected by way of mechanical elements, illustrated as a block ~~614~~430, 440, to the load cell 418. The connections as described in conjunction with FIGURE 6, together with the mechanical arrangements discussed in conjunction with FIGURE 4, make it clear to those skilled in the art that the system as so far described constitutes a degenerative feedback loop which tends to maintain the desired pressure or force on the pin tool. The pressure or force applied to the pin tool by the feedback arrangement can readily be changed by simply changing the reference signal produced by block 610.

Paragraph [0020] on page 9 of the original patent application has been amended as follows:

[0020] The feedback arrangement as described in conjunction with FIGURES 4 and 6 tends to maintain the pressure or force on the spindle 18 and the pin tool 22 at a constant, selected target. According to an aspect of the invention, the target pressure or force is selected to be that pressure or force represented by B of FIGURE 5b, which corresponds to the corner 501, where there is a marked change from a relatively low rate of increase of force or pressure to a relatively high rate of increase as a function of penetration depth. This selection makes it easy for moderate pressures or forces (those lying between A and B of FIGURE 5b) to cause penetration to depth ~~510~~514, but any error in the feedback which gives a value of error signal greater than that required to reach depth ~~510~~514 results in relatively small additional penetration.

Paragraph [0021] on page 9 of the original patent application has been amended as follows:

[0021] The arrangement of FIGURES 4 and 6 may tend to apply forces larger than desired to the pin tool at the beginning of penetration, before the pin tool has reached its full operating depth. According to an aspect of the invention, the reference signal source 610 of FIGURE 6 produces a ramp voltage at initial start-up, which ramps from zero to the desired value, and then remains at the desired maximum value. FIGURE 7 is a plot ~~710~~700 of reference signal versus time according to this aspect of the invention. In plot ~~710~~700, the amplitude of the error signal ramps from zero value at zero time to the desired steady-state value at a time ~~t1~~T1, and remains at the steady-state value thereafter (or until a new plunge is undertaken).

Paragraph [0022] on pages 9-10 of the original patent application has been amended as follows:

[0022] FIGURE 8 is a simplified illustration of a stir friction hot-working or welding arrangement similar to that of FIGURE 4, but including a measuring device or sensor in the form of a linear variable differential transformer (LVDT) 710, which produces signals on a signal path 712 for application to the controller 460. FIGURE 9 is a simplified block diagram of the control system of the arrangement of FIGURE 8. Elements of FIGURE 9 corresponding to those of FIGURE 6 are designated by like reference numerals. In FIGURE 9, motion of the pin tool caused by movement of motor 450 is coupled to LVDT 710, which produces a signal representing pin tool position relative to the surface. The position signals are applied to an encoder ~~912~~917, which may be as simple as a differentiator, for determining the rate of change of position. The rate of change of position signal is applied to a modulator or multiplier 910, which couples more or less of the pressure error signal from error detector 612 to the motor, depending upon the rate of change signal. The purpose of this

arrangement is to prevent application of excessive force to the pin tool during initial penetration, which might damage the system.

Paragraph [0024] on pages 10-11 of the original patent application has been amended as follows:

[0024] Thus, a method according to an aspect of the invention for stir-friction hot-working or welding a planar workpiece (14) uses a rotating pin tool (22) which includes a pin or ligament defining a diameter at locations closer to the tip of the pin tool (22) that is less than a diameter at a particular location on its length, and also including or defining a shoulder (224) at the location. The shoulder (224) has a larger diameter (D) than the pin diameter (d). The method includes the steps of rotating the tool, and applying pressure or force to the pin tool (22) with the pin tool (22) plunged into one side (14us) of the workpiece (14), and with at least a portion ~~(524)~~(524) of the shoulder (224) essentially coincident with the surface (14us) of the one side of the workpiece (14), so that the rotating pin creates a friction-stirred region. According to an aspect of a method according to the invention, the workpiece (14) and the rotating tool (22) are moved laterally (in a direction orthogonal to the axis of rotation) relative to each other (by motor 470, rack 472 and gear 474), so that the friction-stirred region (14b) progresses along the workpiece (14). During the moving step, a signal is generated, which is representative of the pressure or force applied to the pin tool (22). A reference signal is generated (block 610) which is representative of that force (B) which is sufficient to maintain the shoulder (224) against the one surface (14us) of the workpiece (14). The signal representative of the force applied to the pin tool (22) is compared (in error signal generator 612) with the reference signal, for generating an error signal representative of the difference between the force applied to the pin tool (22) and the force represented by the reference signal. The error signal is used to control the step of applying force in a manner tending to maintain the shoulder (224) in

contact with, or essentially coplanar with, the one surface of the workpiece (14), as a result of which, or whereby, the pin (22) maintains a substantially constant plunge depth.